

A RAPID METHOD FOR ESTIMATING THE DRY MASS OF SOIL FROM EROSION RESEARCH PLOTS

Estimates of the dry mass of soil in runoff are required to assess the amounts of soil loss from erosion research experiments. The technique previously used in Rhodesia was to apply a suitable flocculent to the field collection tanks. The supernatant fluid was drawn off after thirty minutes. A small subsample of the sludge was taken and the water evaporated to gain the mass of oven-dry soil (Jackson 1964 a, b).

Evaporation methods require considerable time, staff, space and laboratory facilities. Furthermore, the accuracy of subsampling techniques depends on thoroughly mixing the sediment into suspension, and on the size and number of samples and the sampling technique. Large quantities of sludge are particularly troublesome.

The fixed-volume method overcomes many of these difficulties. It has been used to measure the mass of soil in suspension (Turner and MacLean, 1950; Hamilton, 1970) but has proved particularly useful in dealing with large quantities of settled sludge (Barnett and Holladay, 1965; Watt, 1971). The method is based on the relationship between the mass of a fixed volume of soil-water mixture and the mass of an equal volume of water at the same temperature, as expressed by the following equation (Watt, 1971):

$$M_o = (M_s - M_w) G / (G - 1) \quad \dots 1$$

where M_o = mass of oven-dry soil, M_s = mass of fixed volume of soil-water mixture, M_w = mass of the same volume of water at the same temperature as the sludge, and G = specific gravity of the soil.

Assuming the specific gravity of the soil remains constant, equation 1 becomes:

$$M_o = b(M_s - M_w) \quad \dots 2$$

where $b = G / (G - 1)$.

The application of this method for estimating the mass of oven-dry soil in a wide range of sludge concentrations was investigated at Hatcliffe Agricultural Engineering Centre. The value of b was determined in the laboratory by a regression analysis using equation 2. The laboratory results were tested in the field.

METHOD

LABORATORY

An experimental area had been selected on which erosion research plots were planned for the following season. The soil was a yellowish-red, fine-grained sandy-clay derived from basic igneous rock. Twenty samples were air-dried, sieved to remove organic residues and thoroughly mixed to give a uniform sample.

Thirty-one subsamples of oven-dried soil were prepared ranging in mass from 0.5 to 300 g. Preliminary tests showed that the soil moisture

content became constant after a minimum of 12 hours at a temperature of 105°C. The samples were carefully weighed (M_o) and added to water in a conical flask. A container with a reasonably wide neck was necessary to handle the sludge. The soil was stirred to ensure that the sample was thoroughly dispersed and no air bubbles were trapped in the soil. Water was added to make up the sludge to a fixed volume of 1 207 ml. The sludge was maintained at a constant temperature (17,2°C) and weighed (M_s). The mass of the same volume of water at the same temperature was also recorded.

The equation yielded by a linear regression of M_o (mass of oven-dry soil on M_s (mass of suspension) was then tested using runoff samples from simulated rainfall plots.

FIELD

Small runoff plots (3 m × 1 m) were installed on 14 different locations over the experimental area. Seven of the plots were sited on virgin land and seven on cropped land. Vegetation was removed and simulated rainfall applied at an intensity of 50 mm/h. The total runoff was collected in a trough at the bottom of the plots and led into a collection tank. The time of application of the artificial rainfall was varied so that a wide range of sludge concentrations was obtained. Thirty-two fixed-volume (1 207 ml) sludge and suspension mixtures were collected with soil contents ranging from 1 to 350 g.

The temperature of each sludge sample was taken and the value M_w (at the same temperature) determined from calibration curves. The fixed volumes of sludge were weighed and the mass of oven-dried soil, M_o , estimated from the laboratory-derived regression equation. The samples were then oven-dried and weighed to give the actual value of M_o .

Estimated and actual values of M_o were compared and the percentage error determined.

TABLE 1.—LABORATORY TEST DATA

M_o g	M_s g	M_o g	M_s g	M_o g	M_s g
0	1 124,8	100	1 187,9	200	1 251,3
10	1 132,1	110	1 195,2	210	1 257,3
20	1 138,4	120	1 200,4	220	1 262,5
30	1 145,2	130	1 206,2	230	1 270,0
40	1 151,2	140	1 213,5	240	1 277,5
50	1 157,2	150	1 219,1	250	1 283,0
60	1 163,1	160	1 225,7	260	1 289,9
70	1 167,2	170	1 232,5	270	1 296,7
80	1 176,0	180	1 238,9	280	1 304,5
90	1 180,3	190	1 245,6	290	1 309,7
				300	1 314,8

RESULTS AND DISCUSSION

The laboratory test data are shown in Table 1 and the results of the regression analysis in Fig. 1.

The regression yielded $b = 1,584$, so equation 2 for this soil is:

$$M_o = 1,584 (M_s - M_w) \quad \dots 3$$

A good correlation was obtained (0,997) with narrow 95 per cent. confidence limits. This indicated that the laboratory techniques were satisfactory and that the data satisfied the equation. The specific gravity given by $b = 1,584$ is 2,712. This compares well with the specific gravity (2,720) determined for the top soil by conventional water-displacement methods.

Equation 3 will be valid in the field under the following circumstances: the values of M_s and M_w are recorded at the same temperature; the influence of organic matter is negligible; the specific gravity of the eroded soil particles does not differ significantly from that of the sampled top soil; and the eroded soil particles are sufficiently dispersed and behave with a true specific gravity.

Care was taken to read the temperature of each sludge sample immediately prior to weighing and to obtain the corresponding value of M_w . Organic residues are prevented from entering runoff collection tanks because they cause blockages; organic content was therefore not expected to be a serious problem. The specific gravity of the sludge (2,728) did not differ significantly from that of the sampled top soil (2,720).

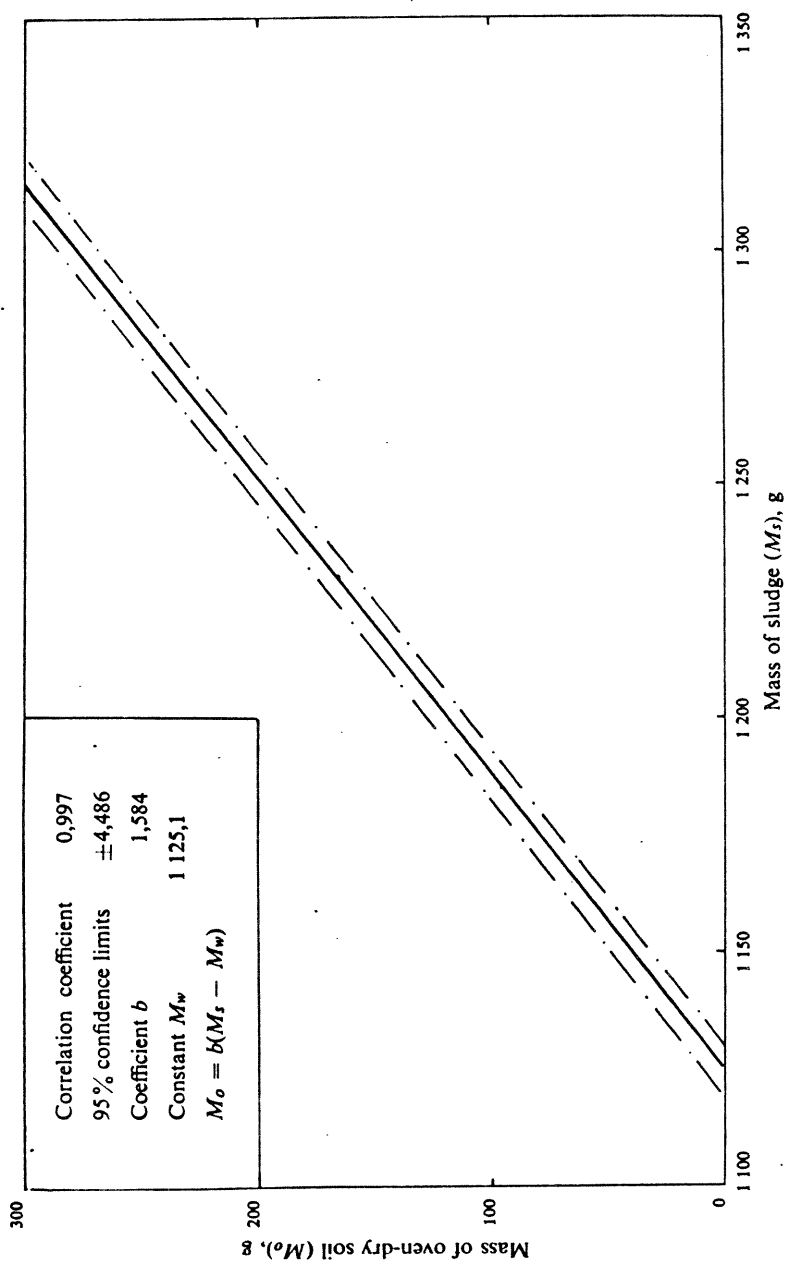
The results of the field test, Table 2, show that equation 3 gives accurate results for sediment concentrations in excess of 30 g/litre. The maximum error recorded was 3,7 per cent. with an average error of 1,44 per cent.

TABLE 2.—FIELD TEST RESULTS

Number of samples	Soil concentration g/litre	Mean error %	Error range
5	350-250	1,4	0,8- 2,5
5	249- 80	1,6	0,4- 3,4
7	79- 30	1,4	0,3- 3,7
15	29- 1	23,6	0,4-77,4

Lower soil concentrations gave unacceptably variable results (0,4-77,4 per cent. error) and a high average error of 23,6 per cent. This was mainly because of difficulties in accurately reading the meniscus levels in the wide-necked flask necessary for handling the sludge. Small errors in estimating the values of M_s and M_w became significant when dealing with small quantities of soil. At these low concentrations a large proportion of the soil remained in suspension. These lighter particles had a much

FIG. 1.—REGRESSION OF MASS OF OVEN-DRY SOIL ON MASS OF SLUDGE



lower specific gravity (2,390) than that of the top soil (2,712). Consequently this was a further source of error.

FIELD APPLICATION

Varying quantities of sludge settle to the bottom of the collection tanks on erosion experiments. In the interests of accuracy and efficiency, the size of the fixed-volume container selected for M_o determinations by direct weighing should correspond to the amount of sludge in the collection tank. Consequently calibration curves of M_w against temperature were drawn for several sizes of fixed volume containers.

In the application of the method under field conditions, the sludge is removed from the collection tanks and weighed. The temperature of the sludge is recorded and M_o read off the appropriate calibration curve. The value of b is constant for the experimental area and M_w is calculated from equation 3.

There are several ways of estimating the amount of soil in the suspension overlying the sludge. The suspension can be flocculated out and weighed with the sludge; alternatively the suspension can be thoroughly mixed, a representative subsample taken, and the value of b in equation 2 calculated from the measured specific gravity of the soil in suspension, as described by Turner and MacLean (1950); or the subsample can be evaporated to dryness.

At Hatcliffe, the suspension is treated with a suitable flocculant which settles the suspended matter within thirty minutes (Jackson, 1964 b). Following this procedure, no sophisticated equipment is required. A series of calibrated fixed-volume containers, a thermometer, a supply of flocculant, and a suitable balance is all that is required.

In these experiments, based on a 1 207 ml volume, a standard balance with an upper limit of 2 kg and a reading accuracy to 0.1 g was used. For large volumes a 20-kg scale with an accuracy of 1 g is adequate.

CONCLUSIONS

The fixed-volume method for rapid measurement of the amount of soil in runoff was tested for Rhodesian conditions. It gave accurate estimates for soil concentrations in excess of 30 g/litre. The average error of 1.44 per cent. was acceptable for field estimation purposes. The value of b needs to be determined for each experimental area. The value of G and hence b , for sludge and soil, were almost identical in the case of the soil type on the experimental site, consequently the conditions for field use of equation 3 were satisfied. Where G for soil and sludge differ the specific gravity of the material forming the sludge should be adopted.

In the field application of this method, the suspended soil is flocculated out of suspension. Following this procedure no sophisticated laboratory equipment is required and the method can be used on remote stations with few facilities.

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